

# Occlusive Disease of the Vessels of the Aortic Arch

## Diagnosis and Management

C. DELMAR JOHNSON, M.D., THOMAS J. ZIRKLE, M.D., AND  
LOUIS L. SMITH, M.D., *Loma Linda*

■ *Physicians should be alert to the possibility of occlusion of one or more of the branches of the aortic arch in any patient having neurologic symptoms or complaint of claudication in the upper extremities. The finding of a pulse deficit in the neck or arm and a blood pressure difference of more than 30 mm of mercury between the two arms is pathognomic of this disease. The presence of the occlusive process can be confirmed and its extent determined by angiography.*

*Vascular reconstruction can be expected to restore normal hemodynamics with gratifying relief of symptoms in the majority of cases.*

THE CURRENT EMPHASIS on the prevention of strokes places the responsibility for early diagnosis of occlusive extracranial vascular disease with the physician. Previously hopeless victims of cerebral vascular insufficiency can now be treated effectively by vascular reconstruction provided the occlusion is in an accessible location in the neck. It is the purpose of this communication to describe the salient features in the diagnosis and management of arterial occlusion involving the vessels of the aortic arch. The symptoms and findings in occlusion of this type are so characteristic that a presumptive diagnosis can be established with a high degree of accuracy by history and physical examination alone.

Occlusive disease of the vessels of the aortic arch was first recognized in 1856 by Savory<sup>12</sup> in a "young woman in whom the main arteries of both upper extremities and of the left side of the neck were throughout completely obliterated." Takayasu, an astute Japanese ophthalmologist, reported in 1908 on retinal changes secondary to occlusion of the great vessels of the neck and thereupon Takayasu's disease became an entity.<sup>13</sup> Martorell and Fabre<sup>9</sup> in 1944 reported from Barcelona on "the syndrome of obliteration of the supra-aortic trunks" and in Europe the designation Martorell-Fabre syndrome continues to be used.

Recently, investigators have tended to include all occlusive diseases of the vessels of the aortic arch in a single entity although the condition may be caused by any of several etiologic factors. The most common obstructive lesion found in the vertebral, carotid and subclavian arteries is an atherosclerotic plaque, with or without thrombosis. The

From the Department of Surgery, Loma Linda University School of Medicine, Loma Linda.

Presented before the Section on General Surgery at the 96th Annual Session of the California Medical Association, Los Angeles, April 15 to 19, 1967.

Reprint requests to: Department of Surgery, Loma Linda University School of Medicine, Loma Linda 92354 (Dr. Smith).

inflammatory arteritis of syphilis and a poorly understood nonspecific inflammatory lesion, as is present in Takayasu's disease, are found but rarely. Crawford and coworkers<sup>4</sup> reporting on 108 lesions in 67 patients, gave this interesting tabulation of the site of occurrence: left subclavian 45, innominate 24, left common carotid 23, right subclavian 15, right common carotid 1. In that series, 41 per cent of the patients had multiple arterial obstructive lesions. Hurwitt and associates noted that cerebral angiography has demonstrated arterial stenosis or occlusion of the vessels of the neck three times more often than cerebral tumors, five times more often than cerebral aneurysm and 15 times more than cerebral arteriovenous malformations.<sup>8</sup>

### Subclavian Steal

One interesting aspect of obstructive lesions of the vessels of the aortic arch is the hemodynamic changes which may be present. Although suspected from the time of Willis (1664)<sup>19</sup> and suggested by Gray<sup>6</sup> in his anatomy text, the actual reversal of blood flow in a vertebral artery was first demonstrated by Contorni<sup>3</sup> in 1960. It was Reivich and coworkers<sup>10</sup> who clinically and experimentally showed the significance of the reversal of blood flow secondary to subclavian obstruction. Since this report in 1961 many investigators have confirmed these findings and the subclavian steal syndrome is now well recognized.<sup>5</sup> Not so well understood is why some patients with subclavian artery obstruction have symptoms of basilar artery insufficiency while some do not. Reivich<sup>10</sup> demonstrated that it requires approximately 10 per cent reduction in the subclavian artery mean pressure to cause reversal of vertebral flow. It takes 50 to 60 per cent occlusion of the lumen of a vessel to cause a decrease in flow through it.<sup>7</sup> The integrity of the circle of Willis is a critical feature and the atherosclerotic changes in the vessels of the neck may be present in these anastomotic vessels as well. Anatomic variations in the vertebral arteries are important. The right vertebral is small in about 10 per cent of people and absent in 3 per cent while the left vertebral is small in 6 per cent and absent in 2 per cent. Occlusion of the major supply to the basilar artery could be disastrous and may have been the cause of the rare serious complications reported following ligation of the vertebral artery.<sup>14,17</sup>

Experimental work on dogs has demonstrated

that reversal of vertebral flow following occlusion of the proximal subclavian artery causes a 41 per cent overall reduction of cerebral blood flow. Exercise of the occluded extremity causes an abrupt increase in muscular blood flow and should therefore abruptly decrease basilar artery flow because of the reversal of vertebral flow, thereby producing basilar insufficiency. Clinically this is true and experimental work by Sammartino and Toole<sup>11</sup> with dogs confirms this chain of events.

Our experience with this problem consists of nine cases, two of which involved occlusion of the innominate artery and seven which involved the left subclavian artery with demonstrated subclavian steal.

### Clinical Material

Table 1 summarizes the symptoms and findings in nine patients having occlusive disease of the branches of the aortic arch. There were five women and four men ranging in age from 43 to 75 years. The most common symptom was dizziness, which occurred in six of the nine patients. Claudication of the involved arm was present in five cases. A palpable pulse deficit was noted in eight patients. The difference in blood pressure between the two upper extremities ranged from 38 mm of mercury in the patient with the least disparity to 94 mm in the patient with the greatest. Visual blurring, hemiparesis and a neck bruit were present in four patients.

Seven of the nine patients in this report had angiographic proof of reversal of vertebral artery flow. In two patients who had brachiocephalic occlusions preoperative aortic arch angiography was not done. Decided narrowing (one patient) or complete occlusion (six patients) of the subclavian artery at or near its origin was observed radiographically and reversal of vertebral flow was noted in all seven cases. These findings were confirmed at operation.

### Operative Considerations

The surgical approach employed in these patients was either a sternal splitting incision with extension into the neck along the anterior border of the sternocleidomastoid muscle or left anterolateral thoracotomy through the fourth intercostal space. The median sternotomy incision was extended in one patient (Case 1 in Table 1) up to the bifurcation of the common carotid artery for the removal of an additional occluding plaque in

TABLE 1.—Summary of Nine Patients with Arterial Obstructions Aortic Arch

Case	Sex	Age	Symptoms	Findings	Blood pressure difference (mm of mercury)	Angiographic Findings	Operative Findings	Operative Procedure	Outcome
1.	M	60	Dizziness Blurring of vision Transient blindness rt. eye Claudication rt. arm Transient lt. hemiplegia	Absent rt. carotid, brachial & radial pulses No bruits present over these vessels Ophthalmodynamometry: O.D. 0/0 O.S. 40/25	94	None performed	Partial innominate artery occlusion Total occlusion origin rt. subclavian artery Partial occlusion origin lt. internal carotid artery	Innominate & rt. subclavian endarterectomy with patch angioplasty Rt. carotid bifurcation endarterectomy with patch angioplasty	Asymptomatic with equal blood pressures both arms Ophthalmodynamometry: O.D. 70/40 O.S. 65/35
2.	M	61	Dizziness Claudication rt. arm Transient blurring of vision	Absent rt. carotid, brachial & radial pulses	50	None performed	Partial innominate artery occlusion & total occlusion rt. subclavian artery	Innominate & rt. subclavian endarterectomy with patch angioplasty	Lt. hemiplegia, respiratory distress with cyanosis, hypotension & death. Autopsy severe pulmonary emphysema, fibrosis & atelectasis
3.	F	57	Stroke with rt. sided weakness 9 yrs. prior to hospital entry	Rt. facial weakness Bruit over lt. carotid artery at base of neck	50	Arch angiogram showed lt. subclavian obstruction with reversal of flow in the vertebral artery	Complete occlusion origin lt. subclavian artery	Lt. subclavian endarterectomy with patch angioplasty	Post op. blood pressures 110/80. Rt. arm 120/80. Lt. arm uneventful recovery
4.	F	43	Dizziness Claudication lt. arm	Weak lt. brachial pulse Bilat. carotid bruits	60	Arch angiogram showed lt. subclavian obstruction with reversal of flow in the vertebral artery	Complete occlusion origin lt. subclavian & partial occlusion lt. common carotid artery at origin	Bifurcation onlay graft from arch to distal subclavian artery & common carotid artery	Horner's syndrome left Blood pressure rt. arm 126/84 lt. arm 158/90
5.	F	57	Dizziness, tingling of lips & tongue, & lightheadedness made worse by exercise of lt. arm	Absent lt. radial pulse Bilateral carotid artery bruits	50	Arch angiogram showed obstruction of the lt. subclavian artery with reversal of flow in the vertebral artery	Complete occlusion origin lt. subclavian artery	Lt. subclavian artery endarterectomy with Dacron patch angioplasty	Restoration of equal pressures in both arms
6.	F	57	Numbness & weakness lt. face Numbness & weakness lt. arm	Absent lt. brachial & radial pulses	44	Complete lt. subclavian artery obstruction at origin with reversal of flow in the vertebral artery	Lt. subclavian artery occlusion at origin of this vessel	Lt. subclavian artery endarterectomy with Dacron patch angioplasty	Restoration of equal pressures in both arms Rt. asymptomatic Lt. Horner's syndrome
7.	M	63	Weakness, paresthesia & loss of fine motor function rt. hand with exercise, numbness rt. side of face & transitory speech difficulty	Weakness grip rt. hand Faint lt. brachial & radial pulses	40	One cm occluding plaque at the origin with reversal of vertebral artery flow	Complete lt. subclavian artery obstruction at the origin of this vessel	Lt. subclavian artery endarterectomy with Dacron patch angioplasty	No pressure gradient between aorta & subclavian artery at completion of surgery. Blood pressure rt. arm 156/80 lt. arm 148/80
8.	F	75	Dizziness, blurring of vision & tingling paresthesia of the lt. side of face	Faint lt. radial pulse Systolic harsh bruit at the base of the neck on the lt.	38	Marked narrowing origin lt. subclavian artery with reversal of vertebral arterial flow	Arteriosclerotic plaque at origin lt. subclavian artery Pressure gradient between aorta & distal subclavian artery was 25 mm Hg.	Lt. subclavian artery endarterectomy with Dacron patch angioplasty	Restoration normal lt. subclavian flow with no gradient between the aorta & distal subclavian artery at completion of endarterectomy
9.	M	60	Episodes dizziness, syncope & diplopia. Prior transitory rt. hemiplegia	Faint lt. brachial & radial pulses	50	Complete lt. subclavian artery obstruction at origin with reversal artery flow	Lt. subclavian artery occlusion at origin of this vessel	Lt. subclavian artery endarterectomy with Dacron patch angioplasty	Restoration of equal pressures in both arms rt. asymptomatic

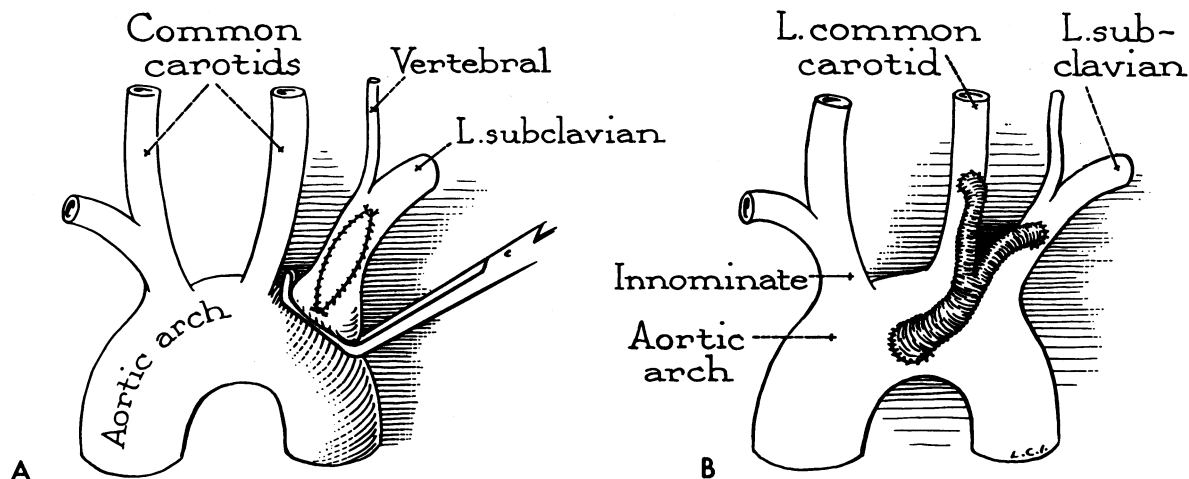


Figure 1.—*Left*, side aortic occlusion, endarterectomy and endogenous patch angioplasty. *Right*, bifurcation onlay prosthetic graft.

this location. Anterolateral thoracotomy was employed in two patients with occlusion at the origin of the left subclavian artery. These incisions were well tolerated and were associated with no morbidity. Closure of the sternum was accomplished with No. 25 stainless steel wire which gave maximum stability.

Endarterectomy followed by a small prosthetic (Dacron®) or autogenous vein patch angioplasty (Figure 1-A) was adequate in all but one of the patients. Extensive atherosclerotic involvement of the arch of the aorta in this particular patient made it necessary to employ a by-pass graft since side clamping of the aorta at the origin of the left subclavian artery also occluded the origin of the left common carotid artery. Reestablishment of the subclavian and left vertebral artery flow was done first by suturing in place a Dacron bifurcation graft to the aortic arch with anastomosis of one limb of the prosthetic vessel to the side of the subclavian vessel. A temporary polyvinyl shunt was placed within the common carotid artery while the posterior portion of the second limb of the bifurcation graft was sutured to this vessel. The shunt was removed and the anterior portion of the anastomosis was completed (Figure 1-B).

A Dacron or autogenous vein by-pass graft should be used between the aortic arch and the left subclavian artery for patients in whom the origins of the left common carotid and subclavian arteries are so close together that the application of a side occluding clamp to the aorta cannot be accomplished without occluding the carotid vessel. Such a shunt can be employed when it would be surgi-

cally difficult to expose the origin of the left subclavian artery. This operative procedure obviates inadvertent occlusion of the carotid artery and avoids injury to the aortic arch.

### Results of Operation

The results of operation in these patients were excellent. Pulses were restored to the involved extremities and the difference in blood pressure gradient between the two arms was corrected. Weakness and claudication in the involved extremities were relieved and the vertigo and lightheaded feeling which had accompanied exercise of the arm disappeared. All patients were subjectively improved. The single postoperative death seemed unavoidable because of concomitant very severe chronic pulmonary disease. In retrospect the patient should not have been selected for operation.

In two patients Horner's syndrome developed after operation. Both had left subclavian occlusion and the damage to the cervical sympathetic nerves probably occurred as a result of mobilization of the proximal subclavian artery with interruption of nerve filaments from the inferior sympathetic ganglion which arch beneath the artery as Ansa subclavian fibers. In subsequent cases, great care has been taken not to damage sympathetic fibers in this area and the complication has not occurred.

### Discussion

Occlusive disease of the branches of the aortic arch can produce several syndromes, depending upon the location of the lesion. Proximal subclavian or brachiocephalic occlusions with reversal

of vertebral artery flow give rise to basilar artery insufficiency. Symptoms here may be vague but usually include varying degrees of vertigo, nausea, numbness of the mouth, diplopia, dysphagia and dysarthria, paresis or paralysis of one to four extremities in any combination due to pyramidal tract involvement at the decussation. Exercise of the involved extremity ordinarily precipitates the patient's symptoms, since blood flow to the arm is abruptly increased with further demand for vertebral collateral flow. Dizziness was the most common complaint in our group of patients, a finding which parallels the observation of Wheeler,<sup>18</sup> who reported this symptom in 11 of 13 patients with aortic arch occlusions.

Occlusion of the carotid artery at its origin characteristically causes weakness or numbness of the contralateral extremities as well as ipsilateral blurring of vision or momentary blindness and contralateral homonymous hemianopsia. Four patients in this study complained of visual disturbance.

Brachiocephalic artery occlusion can give rise to an interesting clinical syndrome. Obstruction of the subclavian artery causes claudication of the right arm and occlusion of the common carotid artery at its origin on the right side gives rise to weakness and sensory changes in the left arm and leg as a result of cortical ischemia.

The physical findings in aortic branch occlusion are more specific and striking. There was a carotid or radial pulse deficit in eight of the nine patients in this series. Bryant and Spencer<sup>1</sup> called attention to this important finding in their report of 14 patients with occlusions of the branches of the aortic arch. There will be a blood pressure difference between the two arms of at least 30 mm of mercury, and some investigators believe that a difference of 20 mm should arouse suspicion of arterial occlusion.<sup>11,15</sup> In this study the blood pressure difference between the two arms ranged between 38 and 94 mm of mercury. Callow<sup>2</sup> emphasized the ease with which the diagnosis can be established when there is a pulse deficit and a disparity in blood pressure between the two arms. All patients but one in the present series had been heavy smokers for many years, suggesting that this may have been a factor in vascular injury.

Angiographic studies provide important information regarding the site and extent of the occlusion as well as whether reversal of flow is present in the vertebral artery. It is impossible to assess the degree of narrowing of an involved artery by

palpation of the peripheral pulse.<sup>16</sup> The presence of an arteriosclerotic plaque in a vessel supplying the brain, even though minimal occlusion is present, may be the source for platelet or thrombotic emboli, resulting in cerebral symptoms and findings. Accurate angiographic delineation of such a plaque is helpful in the selection of patients for operation.

## REFERENCES

1. Bryant, L. R., and Spencer, F. C.: Occlusive disease of subclavian artery, *JAMA*, 196:123-28, Apr. 1966.
2. Callow, Allan D.: Surgical management of varying patterns of vertebral-artery and subclavian-artery insufficiency, *New Eng. J. Med.*, 270:546-52, 12 Mar. 1964.
3. Contorni, L.: Il circolo collaterale vertebro-vertebrale nella oblitterazione dell'arteria suclavia alla sua origine, *Minerva Chir.*, 15:268, 1960.
4. Crawford, E. S., DeBakey, M. E., Morris, G. C., and Cooley, D. A.: Thrombo-obliterative disease of the great vessels arising from the aortic arch, *J. Thorac. Cardio. Surg.*, 43:38-53, Jan. 1962.
5. Editorial. A new vascular syndrome: "The subclavian steal." *N. Eng. J. Med.*, 265:912, 1961.
6. Gray, H.: *Anatomy: Descriptive and Applied*, Twenty-second edition, Longmans, Green and Company, London, 1923, p. 636.
7. Heyman, A., Young, W. G., Dillon, M., Goree, J. A., and Klein, L. J.: Cerebral ischemia caused by occlusive lesions of the subclavian or innominate arteries, *Arch. Neurol.*, 10:531-39, June 1964.
8. Hurwitt, E. S., Carton, C. A., Fell, S. C., Kessler, L. A., Seidenberg, B., and Shapiro, J. H.: Critical evaluation and surgical correction of obstructions in the branches of the aortic arch, *Ann. Surg.*, 152:472-84, Sept. 1960.
9. Martorell, Otzet, F., and Fabre, T. J.: El síndrome de oblitteracion de los troncos supra aorticos, *Medicina Clin.*, Barcelona, 2:26-30, 1944.
10. Reivich, M., Holling, H. E., Roberts, B., and Toole, J. F.: Reversal of blood flow through the vertebral artery and its effect on cerebral circulation, *New Eng. J. Med.*, 265:878-85, 2 Nov. 1961.
11. Sammartino, W. F., and Toole, J. F.: Reversed vertebral artery flow; The effect of limb exercise and hypertensive agents, *Arch. Neurol.*, 10:590-94, June 1964.
12. Savory, W. S.: Case of a young woman in whom the main arteries of both upper extremities and of the left side of the neck were throughout completely obliterated, *Tr. Med.-Chir. Soc.*, London, 39:205, 1856.
13. Takayasu, M.: Case of queer changes in the central blood vessels of the retina, *Acta Soc. Ophthal. Jap.*, 12: 554, 1908.
14. Thomas, G. I., Anderson, K. N., Hain, R. F., and Merendino, K. A.: Significance of anomalous vertebral basilar artery communication in operations on the heart and great vessels, *Surgery*, 46:747, 1959.
15. Toole, J. F.: Reversed vertebral-artery flow; subclavian steal syndrome, *Lancet*, 1:872-73, 18 Apr. 1964.
16. Warren, R., and Friedman, L. J.: Pulseless disease and carotid artery thrombosis. Surgical considerations, *New Eng. J. Med.*, 257:685, 10 Oct. 1957.
17. Webb, W. R., and Burford, T. H.: Gangrene of the arm following use of the subclavian artery in a pulmonary-systemic (Blalock) anastomosis, *J. Thorac. Surg.*, 23:199-207, 1952.
18. Wheeler, H. B.: Surgical treatment of subclavian-artery occlusions, *New Eng. J. Med.*, 276:711-17, 1966.
19. Willis, T.: *Practice of physick*, S. Pordage, London, 1634, Part 6, p. 59.